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VOLCANOES

AND

CORAL REEFS.

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VOLCANOES AND CORAL REEFS.

A LECTURE

DELIVERED AT THE BIRKBECK INSTITUTION, LONDON.

IN the modification of our globe the force of heat has at all times played an important part, and perhaps its most striking phase is that of volcanic action, the phenomena connected with which still form prominent features in the grand panorama of Nature.

Whatever may be the source of the heat of the globe, it is matter of common knowledge that somewhere beneath its surface a quantity of heated material exists, and that the efforts of that material to burst its rocky prison result in the phenomena of earthquakes and volcanoes. As to the manner in which these materials are disposed beneath the earth's crust there has been much dispute, and the matter, even now, can scarcely be considered to be set at rest. According to the older view, the earth consists of a hollow shell, from one to two hundred miles in

thickness, the whole of the interior being in a highly heated molten condition. The more modern theory is that the earth is more or less solid throughout, but that here and there, within a a few miles of the surface, there exist isolated accumulations of heated material, which have a constant tendency to break through the overlying rocky crust and escape to the surface.

In favour of the first of these theories we have the undoubted fact that the temperature of the earth's interior steadily increases in all parts of the globe as we get nearer the centre. In all mines and other excavations of the earth's interior it is found that for the first ninety feet, or thereabouts, below the surface the temperature of the crust of the earth varies with the climate and with the seasons; but that below this *zone of variable temperature*, as it is termed, the temperature is found to be the same throughout the year, and that it increases at about the rate of one degree Fahrenheit for every sixty feet of descent into the interior. Local circumstances, of course, affect this progressive increase; but, taking a series of observations in various parts of the globe, the figures are, on the average, those just stated. Another argument in favour of the older theory as to the condition of the earth's interior is the wide-spread existence of volcanoes and earthquakes, and the identity of the materials ejected by volcanoes wherever they exist. Again, it is urged that if the progressive increase of temperature noticed above be maintained, the heat will be so great at a depth of one or two hundred miles beneath the surface that even the most refractory substances known must infallibly succumb to its influence, and assume the liquid, if not the gaseous condition —platinum, the metal which has the highest melting point, being fused at a depth of about thirty-five miles. Against these arguments in favour of the fluidity of the earth's interior numerous objections have been urged. Amongst others may be mentioned

the following. The centres from which earthquake action originate are, as recent research has conclusively shown, situated but a few miles—certainly not more than thirty—beneath the surface. Again, were the material ejected by volcanoes obtained from a common source, upon the principle of the equilibrium of fluids, the lava in the craters of volcanoes in all parts of the world should stand at the same height, which it most certainly does not. Finally, if the interior of the earth be entirely molten, the same influence which produces tides upon the surface would produce tides in the interior, and these would infallibly burst through a crust less rigid than one of the hardest steel. These objections are of great weight, and, on the whole, it is more probable that the modern theory, which supposes the globe to be tolerably solid, is the correct one; but, however this may be, we will now turn our attention to the nature of the phenomena to which the earth's internal heat, however disposed, undoubtedly gives rise. The nature of volcanoes and earthquakes may best be understood by considering briefly some of the most important examples of each.

The district of the Mediterranean Sea has long been celebrated for its volcanoes, and one of the most picturesque is undoubtedly that of Stromboli in the Lipari Islands, which was in much the same condition as at present, even in Homer's day. Continually emitting flames, ashes, and lava, it forms a natural lighthouse, illuminating the sea far and wide with its ruddy light. The opening from which the lava comes is on the side, and not upon the top of the mountain.

If we examine an imaginary vertical section of a volcano we find that it consists of a conical hill or mountain, in the top of which is a basin-shaped depression, the *crater*. Running up the centre of the mountain, and opening into the crater, is the main chimney, or vent, while numerous fissures exist in the sides of the

cone, some of which do, and some do not, reach to the surface. From those which reach the air streams of lava flow during an eruption, while similar molten material is injected into those fissures which are entirely subterranean. In the course of time this latter material solidifies, and the action of the atmosphere wearing away the softer overlying rocks, the cooled lava is left in the shape of walls, or "dykes," as they are termed, sometimes running for miles across a hilly country, which was in former times volcanic. Much less frequently, the lava is softer than the surrounding rocks, and if in any way the atmospheric agents gain access to it, it decays, and leaves grooves and hollows behind it. From this it will be seen that the term "burning mountain," so frequently applied in popular phraseology to volcanoes, is a misnomer. The volcano is not itself burning, but only the material which it ejects : a volcano is simply a chimney, or vent, by which subterraneous heated material finds its way to the surface.

To account for the origin of volcanic cones two theories have been propounded. One, known as the *Elevation theory*, supposes that the cone is formed by the swelling-up of the rocks into a bubble-shaped heap, which bursts and gives rise to the cone and crater. The other theory, known as the *Eruption theory*, supposes that the cone results from the gradual piling-up of the ejected material round the central orifice, and the manner in which the rocks of a volcanic cone are disposed most decidedly favours this conclusion, which is now generally accepted as the correct one. The materials ejected in a volcanic eruption are solids in the form of blocks of rock, varying in size from small pieces the size of a nut up to blocks weighing several tons, rock-ash, and extremely fine dust. Liquids are represented by molten rock or lava. Gaseous materials are emitted in the shape of steam, sulphuretted ogen, and other gases.

One of the most remarkable volcanoes in the world, whether we consider its present condition or its past history, is Vesuvius, in the south of Italy. Up to about the year A.D. 79 this mountain had given no signs of activity, and was considered to be quite extinct; vines covered its slopes, and its crater was covered with grass and shrubs. In this year, however, the mountain began to give signs of uneasiness; tremblings of the earth were frequent, and earthquakes, gradually increasing in force and frequency, culminated in that memorable eruption which overwhelmed the populous cities of Herculaneum and Pompeii, which, after nearly eighteen centuries of oblivion have in modern times been brought again to light. Pliny the younger, as every one knows, wrote a very complete account of this eruption to Tacitus the historian, and, as the phenomena agree very well with what has subsequently been noticed in various parts of the world, I will refer to it at length.

For some days before the eruption a huge cloud, the shape of an Italian pine tree, flattened out at the top something like an umbrella, hung over the mountain. This cloud, which is a common feature in volcanic eruptions, is not, as popularly supposed, composed of smoke, but consists of an immense quantity of very fine dust and steam. It has been estimated that in such a cloud, at any one moment, as many as twenty thousand cubic yards of water are held in suspension. From this cloud immense showers of dust fell upon all the surrounding country, including the cities of Herculaneum and Pompeii. Then, when a considerable deposit of this fine dust had accumulated, the steam becoming condensed came down in torrents of rain converting the dust into a fine liquid mud, and by a flood of this so-called, *water-lava, (lava d'aqua)*, both Herculaneum and Pompeii were overwhelmed. No true lava reached these ill-fated cities at that time, showers of ashes and torrents of lava d'aqua alone effected the work of destruction, and

although Herculaneum is at present buried beneath true lava, it is quite certain that none of it is older than the tenth century. The penetrating character of the fine mud enabled it to enter the smallest cavities, and to this fact we owe the preservation of so many interesting memorials of life in a fashionable watering-place eighteen centuries ago. Since this historic eruption Vesuvius has been in a state of constant activity, and several very terrible eruptions have occurred. In 1829 a new crater, (the present one), was opened in the old one, which was of much greater extent, and some two thousand feet deep.

A very remarkable volcano, and one much loftier than Vesuvius, is Mount Etna, on the eastern coast of Sicily, which reaches a height of between ten and eleven thousand feet. This mountain is divided into three regions, at its base is an extremely beautiful and fertile region, above this a belt of forest some seven miles in breadth, and above this again a barren desert region covered with snow through the greater part of the year. The central cone rises from the centre of this district, above which it towers to a height of nearly eleven hundred feet. This central cone is not, however, the part of the mountain which displays the greatest volcanic energy ; we must look for that in the forest region. From this region arise over seventy volcanic cones, from which at various times immense streams of lava have flowed. Mount Etna thus forms a kind of compound volcanic mountain.

As a contrast to such a compound volcano we have in the Phlegræan Fields near Vesuvius a small volcanic mountain, or rather hill, which is at present to all appearance extinct, but the history of which is very curious and interesting. Until the year 1533 there existed on the spot now occupied by this volcano a town named Tripergola. In this year numerous earthquake shocks were felt in the neighbourhood, and at length the ground suddenly

sank fourteen feet. Quickly it rose again like an immense bubble and then, as bubbles will, burst, forming a basin-shaped depression with an aperture in the centre, from which flames, steam, and volcanic-ash were emitted, and in twenty-four hours the city of Tripergola had given place to a mountain a mile and a half in circumference at its base, and 440 feet in height. This mountain is known as Monte Nuova, and since its formation it has shown no signs of volcanic activity, its sides and crater being at the present day covered with grass.

Here nature was as it were caught in the act of forming a volcano and we see the nature of the entire process from beginning to end. Other similar instances are also known. In Mexico there is a chain of six volcanic peaks, known as the Jorullo, and these were upheaved in a few weeks, their formation being preceded by earthquakes, and the opening of an enormous chasm through which were ejected the materials of which the peaks are composed; the loftiest of these is sixteen hundred feet in height.

A region which has always been noted for its grand exhibitions of volcanic energy is Iceland, and during some of the most terrible of these eruptions the discharges of lava have been enormous, almost beyond conception. Hecla, in the south of the island, is the loftiest peak, being about four thousand five hundred feet in height. Nearly fifty eruptions of this mountain are recorded, the most terrible being one which took place in 1783. Skaptar Jokul, a neighbour of Mount Hecla, however, carries off the palm for enormous energy. In 1783, during an eruption it discharged more lava than the Nile discharges water in a year. This was emitted in two enormous streams, one fifty miles long and twelve miles wide, the other forty miles long and seven miles broad. Altogether Skaptar Jokul in this single eruption poured out, as Sir Charles Lyell estimated, sufficient lava to fill up all the valleys and cover up all the hills

from London to Gloucester with a coating from one to five hundred feet in thickness. From the effects of this eruption thirty thousand people perished. Streams of lava are popularly supposed to be in appearance like streams of liquid fire, but this is to a great extent a delusion. Seen at night, immediately they issue from the volcano, they do have such an appearance, but lava cools very quickly, and a crust is soon formed over the streams which generally look more like rivers of mud than anything else, especially when, as is generally the case, they are covered with ashes and dust. The crust which forms over the lava is a very bad conductor of heat, and consequently while the top of a stream is hard and firm, the interior retains for a long time its heated, and even molten condition.

Two very striking volcanoes are Mounts Erebus and Terror, which are found in the gloomy Antarctic regions. These giant warders of the southern continent illumine with their hideous light those desolate regions of perpetual ice and snow. Mount Erebus, the loftier of the two, reaches an altitude of twelve thousand four hundred feet.

The Andes, which form the back-bone of South America, are mostly volcanic, and one of the most remarkable peaks is Cotopaxi which, rising to a height of about nineteen thousand feet, has its summit covered with perpetual snow. Above this enormous peak the flames rise some three thousand feet, forming a most imposing spectacle. A peculiar feature of the South American volcanoes is the entire absence of lava, solid and gaseous materials being alone emitted.

The largest volcano in the world is undoubtedly Kilauea in the Sandwich Islands. It is in a state of constant activity, and at intervals suffers eruptions of a very magnificent and startling character. The floor of the crater is a mass of black seething lava, -eral square miles in extent, from which numerous columns of

smoke and sulphureous gases ascend. When in more active eruption the crater becomes converted into a sea of fire, while fountains and cascades of flame are tossed high in the air, or fall over tremendous precipices. The sight is described by travellers as being of the most awful and fascinating character, and one to which no description can do justice; the crater is ten or twelve miles in circumference.

Volcanoes are not confined to dry land, but frequently occur beneath the sea. The great eruption of Skaptar Jokul in 1783 was heralded by the sudden upheaval of a small island between Iceland and Denmark. To this the King of Denmark immediately laid claim, but Father Neptune speedily resented this attempt to interfere with his "ancient solitary reign," for in a few months it disappeared beneath the ocean as suddenly as it had been upheaved. A fine example of a submarine volcano is to be found in the island of Santorin in the Grecian Archipelago, which with the neighbouring islands is arranged in a form suggestive of the crater of a volcano. These islands have been thrown up by volcanic action at various dates, the oldest of them having been thrown up so far back as one hundred and ninety-eight years before the Christian era.

In addition to such active volcanoes as those described above, and of which there are altogether nearly four hundred, there are in many parts of the world the remains of volcanoes which are totally extinct. Auvergne in France, and the Eifel in Germany, afford numerous instances of extinct volcanoes.

Between the two great classes of volcanoes, active and extinct, we have cones which emit materials of a less highly heated character than those emitted by such active volcanoes as Vesuvius. These occur in districts where volcanic energy is evidently dying out, and usually emit either warm mud, sulphureous gases, or steam.

They are usually hills of low elevation only, and the materials ejected vary in temperature from that of boiling water or higher, down to a temperature but little above that of the surrounding air. A good example of a series of mud volcanoes is found in the Crimea, and numerous examples of air volcanoes occur in South America, near Quito.

Closely connected with volcanic energy are the numerous hot wells and boiling springs which occur in many parts of the world. The most celebrated boiling springs are the Geysers of Iceland. In the northern part of this island more that fifty geysers may be seen in the space of a few acres. The largest of these is the Great Geyser, which rises from a mound of flinty earth about thirty feet high and two hundred feet in diameter. On the top of this mound is a basin sixty feet wide and seven feet deep, and in the centre of this basin is the opening of a pipe which leads into the earth. Here we at once perceive the likeness existing between a geyser and a volcano. The basin and pipe are lined with a coating of siliceous material, and huge crystals of the same substance, in appearance not unlike cauliflowers, are scattered round the basin. Small eruptions of the geyser occur about every three hours, but the grandest displays occur only once in thirty hours. These are preceded by a hollow rumbling noise, and by loud subterranean explosions which shake the earth. Suddenly a huge column of boiling water and vapour shoots up, with a somewhat fluctuating motion, to a height of eighty or ninety feet. From this central pillar numberless smaller jets rise to a much greater height, and when the steam is blown aside by the wind, the central column of water is seen to spread itself out at the top in the same manner as the cloud does in a volcanic eruption. At intervals the column of water suddenly subsides, but is immediately shot up again with an accompaniment of subterranean explosions and rumbling noises.

The whole eruption lasts about ten minutes, and at its close the water in the basin is found to be nearly boiling, while that in the pipe is many degrees above the boiling point.

The largest known geyser is the Giantess of the Yellowstone River in North America. In this case the crater is on level ground, and not on a hill, as is most generally the case. The displays last twenty minutes, and the main jet of water and steam rises to a height of sixty feet, while smaller jets reach a height of about two hundred and fifty. In all eruptions of geysers the termination of the display is heralded by a jet of steam unaccompanied by water.

Besides these absolutely boiling springs, others occur in great abundance in which the water is hot or merely warm. Of hot wells, the most remarkable are those on Gardiner's River, a tributary of the Yellowstone in North America. These are situated in a district covered with volcanic ashes, and emit suffocating sulphureous vapours.

Geysers, boiling springs, and warm wells, undoubtedly have their origin in the same subterranean heat as that which gives rise to volcanoes. The explanation of the intermittent eruptions of the geysers is very simple. The pipe opening into the basin or crater leads down into the earth, and, bending nearly at right angles to itself, communicates with a subterranean reservoir in the heated rocks. Water percolating through the overlying rocks gradually accumulates in this cistern. There it becomes heated and partially converted into steam, which steam, having its pressure increased by the heat of the surrounding rocks, presses upon the surface of the water and forces it up the pipe into the crater of the geyser. During the interval between the two eruptions the water is accumulating in the cistern, and steam being formed.

A well-known phase of heat action is seen in those disastrous

phenomena—earthquakes. With the general features of these occurrences we are all familiar from the reports of eye-witnesses, though, happily, we have in this country no personal experience of them. As a general rule they are heralded by signs similar to those which precede a volcanic eruption. The air for days before is heavy and stifling, tremblings of the earth, causing nausea and giddiness in man and animals are felt, subterranean noises like the clanking of chains or the discharges of artillery are heard, and storms accompanied by thunder and lightning frequently occur. Then comes the final outburst, the earth is upheaved, houses and buildings of every kind are thrown down, and in a few minutes the work of destruction is complete.

One of the most terrible visitations of which we have any record was the earthquake by which on the first of November, 1755, the handsome city of Lisbon was destroyed. Contrary to common experience, this earthquake was not preceded by any of the usual signs. The sun rose bright and beautiful on that eventful morning, everything wore its accustomed aspect, men went about their business or their pleasure without any foreboding of ill, when suddenly the outburst came, and in a few moments the stately city was changed into a shapeless heap of tottering ruins, and sixty thousand of the inhabitants were without warning hurried into eternity. A peculiar feature of this eruption was the sudden submergence of a large marble quay, which had recently been constructed at great expense. Alarmed by the falling buildings, a large number of the inhabitants rushed for safety to the quay, which soon became crowded, when suddenly it sank with every soul upon it, and not a vestige of it was ever seen afterwards; it disappeared, and literally

> Like an insubstantial pageant faded,
> Left not a wrack behind.

Another peculiar feature which frequently accompanies an earth-

quake was also witnessed on this occasion. The Tagus suddenly receded from its banks, leaving the bottom of the river dry, and then as suddenly swept in again with tremendous violence, reaching the central parts of the city, and adding yet another drop to the overflowing cup of its inhabitants' calamity. This earthquake was felt over a very wide area. The actual shock was felt in the north of Africa, and in the south of Norway, Sweden, and the British Islands, while secondary effects were experienced in North America and the West Indies. In the latter district the usually small tides were suddenly augmented, and the sea was churned up until its waters became as black as ink.

Another terrible earthquake, or rather series of earthquakes, was that of Calabria, which, commencing in 1783, lasted nearly four years. During this terrible period about sixty thousand persons perished, and the destruction of property was equally disastrous. Many curious effects in the alteration of the level and position of the land were observed. It is usually considered that the American story of one man's field being placed by an earthquake upon the top of that belonging to another is a choice specimen of humorous mendacity, but in the Calabrian earthquake several instances of this actually occurred; portions of land were removed bodily from a higher to a lower level. In one place a chasm was opened in the side of a hill; in another a mass of land was deposited in a river and blocked up its course, the removal being effected so gently that trees were left standing and continued to grow in their new situation.

In 1822 an earthquake occurred in Chili, in the western coast of South America, and affected about twelve hundred miles of sea coast, permanently changing the level. For hundreds of miles the sea coast was raised, and many places which formerly afforded anchorage for large vessels were, after the earthquake, too shallow for that purpose.

In 1819 an earthquake occurred in a district known as Cutch, at the mouth of the Indus, and in this case the result was a general lowering of the land, though in places a little distance away an elevation of the land took place—the land, in fact, was bent and crumpled up. Numerous theories have been propounded to account for earthquakes and volcanoes, but the one now generally received, and which certainly seems to fully and clearly explain the phenomena, is due to Mr. Mallet. Water is undoubtedly at the bottom of the matter, for fish and other aquatic objects have been thrown out from the craters of volcanoes. In the cooling of the earth, which takes place unequally in different parts, some portions of the earth's crust become harder and denser than others, and so we get lines of strength and lines of weakness. As the crust cools considerable pressure must be exerted upon the central portions, and pressure means heat. This heat has in many parts been sufficient to liquefy the rocks, and produce subterranean reservoirs of lava. Water percolating through the rocks reaches these reservoirs, and becomes converted into steam, the pressure of which soon becomes sufficient to rend the earth's crust at its weakest parts. If the resistance be very great, an earthquake occurs; if not so great, a volcano is the result—an earthquake being an unsuccessful attempt to establish a volcano. Thus we see that the agency which probably causes these tremendous convulsions of nature is identical with that which works our machinery, and serves so efficiently the purposes of locomotion—steam. And we must remember, too, that just as our steam boilers require a safety valve, so does the subterranean vapour require some outlets, and these it finds in those great natural safety valves, earthquakes and volcanoes. Terrible as these phenomena appear, disastrous as are their effects, they, like everything else in nature, have a beneficent purpose to fulfil. In addition to giving

vent to the internal heated material, these phenomena have, by twisting and tilting over portions of the earth's crust, brought within man's reach a quantity of mineral wealth, which would otherwise have lain far beneath the surface, and beyond his ken.

It is not improbable that the connection between volcanoes and coral reefs is not readily apparent to all, but a little consideration will show that there is a connection of an important character. The white arborescent material which we see in museums and occasionally in cabinets in dwelling houses is, as every one knows, the product of a minute animal, the coral polype, which labours incessantly beneath the seas in the regions of eternal summer. The red material which is made into gum-rings and necklaces for the use of the rising generation, and which is also termed "coral," is not the most important kind, and our description does not in every way apply to it, but to the white variety only.

A good idea of the coral polype may be gained from a consideration of the much more familiar "sea-anemone," to which it is distantly related. Every visitor to the sea-side has seen at low tide the short cylindrical, leathery-looking sea anemones attached to the rocks, their tops surmounted by a circlet of fine filaments or "tentacles," which give it that flower-like appearance which suggested its name. If we examine one of these little animals carefully we see that in the centre of the circlet of tentacles is an aperture, the mouth, which leads into a blind sac, the digestive sac, the single aperture at the top serving both for an inlet for nutritious substances and as an outlet for waste material. When anything good to eat comes within range of the tentacles they close round it and draw it into the digestive cavity, where it undergoes processes analagous to those which take place in our own bodies, whereby the nutritious portions are rendered fit for absorption into the general system. Should the animal get hold of something too

large for the capacity of its stomach, it gets out of the difficulty by splitting itself in two, each half growing into a perfect animal. In addition to thus multiplying by "fission," the little coral animals multiply by "budding." A small bud grows out of the side of the body, and gradually assumes the shape of the parent stem, from which it sometimes becomes detached, and begins life on its own account. A third method of multiplying is by the production of eggs, which are hatched, and the young passed out of the mouth. The young are small oval bodies, provided with numerous hair-like vibratile filaments, termed "cilia." By means of these cilia the young polype swims about, often travelling for some distance from its parent, and at length, having apparently sown its wild oats, it loses its cilia and settles down upon the bottom of the sea. There it anchors itself permanently, and, continuing to grow, gives off buds, and these buds give off others, so that you soon get a kind of living tree, the open mouths of the polypes, with their circlets of tentacles, representing flowers. These coral polypes have the power of extracting from the sea-water in which they live carbonate of lime. This they deposit in the interior of their bodies, until a skeleton, which is a complete model in carbonate of lime of the colony of polypes, is formed. When the polypes die the soft parts decay, and the skeleton is left in the form of coral. In some cases the skeleton acquires a red tint, and forms red coral, but in these colonies the skeleton is far less complete than in the white variety, where there is a skeleton for each individual polype, as well as for the common stem. As successive generations of polypes die, others build upon their skeletons, and so in the course of ages immense deposits of coral have been formed.

On examination of the various deposits of coral in different parts of the world it is found that they occur in three forms, known

respectively as "fringing reefs," "barrier reefs," and "atolls," or coral islands. The island of Mauritius in the Indian Ocean affords a good example of the first variety. All round the island is a kind of terrace formed entirely of coral, extending about a mile from the shore, and at the edge this rises into a kind of rim over which the waves dash and foam. Inside the reef the sea is very shallow, but outside it suddenly deepens. The coral polypes flourish best on the edge of the reef in the surf, but they also live and work beneath the surface down to a depth of about a hundred and fifty feet, beyond which it is certain that they cannot live. The space between the reef and the land is termed the lagoon, and the bottom of this is formed by a kind of coral mud formed by the waves dashing over the natural breakwater formed by the edge of the reef, detaching fragments and grinding them to powder. Numerous examples of the fringing reef occur in other parts of the world, but the one cited above is perhaps the best example of a simple reef. Barrier reefs are often of enormous size, one on the east coast of Australia being more than eleven hundred miles long, and from one to several miles in width. This reef is separated from Australia by a channel about a hundred and fifty feet deep, while outside the reef the sea is two or three thousand feet deep.

The third variety of coral reef, the atoll, consists of an incomplete ring of coral rising up in the middle of the ocean, apparently unconnected with any land. In its centre is a shallow lagoon, and the top of the reef is covered with beautiful vegetation, sprung from seeds dropped by birds, or carried thither by winds. On one side of the reef is an opening, and through this ships can obtain entrance to the lagoon, which forms an admirable natural harbour. Outside of the reef the soundings rapidly increase in depth, until at the distance of less than a mile they reach over three thousand feet. If the ocean floor were laid bare these atolls would be seen

to rise up as huge conical hills with indented tops, much resembling the crater of a volcano.

The occurrence of these three varieties of coral reefs was for a long time a puzzle to scientists. In spite of the fact that the coral polypes cannot live at a greater depth than from one hundred and twenty to one hundred and fifty feet beneath the surface, we have these immenes masses of coral thousands of feet in thickness. After several attempts to solve the problem, the question was at length set at rest by that great naturalist Charles Darwin, who has rendered such valuable service to the cause of science. In a work upon the subject, Darwin has fully expounded his theory, and it is roughly this: The areas where barrier reefs and atolls exist are, and have been for ages, slowly sinking, and the polypes in their building have kept pace with this subsidence. If we assume the existence of an island in a coral sea, we have no difficulty in understanding how the polypes would build upon it a fringing reef, the depth of the coral below the surface never exceeding a hundred and fifty feet. Now suppose that the island slowly sinks, and that as it sinks the polypes continue to build. It is clear that in time we should have a barrier reef at some distance from the land, with a shallow sea inside and deep ocean beyond. Let the sinking continue until the island is completely submerged and you will have an atoll, a circular reef of coral unconnected with visible land, and with a shallow lagoon in the centre. That this hypothesis is tenable has been subsequently shown by the discovery of the fact that the land is in many other parts of the globe either slowly rising or slowly sinking. The northern part of the coast of Scandinavia is known to be slowly rising, while the southern portion is slowly sinking. The eastern portion of the South American continent has for ages been undergoing gradual upheaval, as shown by the numerous raised

beaches which exist there, with the remains of marine animals such as barnacles, clinging to rocks far inland, as we now see them on cliffs upon the sea-coast. In fact, the land which we are so accustomed to refer to as the type of everything fixed and unchangeable, is in constant though gradual motion, rising here, falling there, and its surface like that of a troubled ocean seldom entirely sinks to rest. A further proof of the correctness of Darwin's hypothesis is to be found in the fact that volcanoes exist only in districts which are either stationary or slowly rising and are never found in company with atolls. The cause of these gradual movements of the earth's crust is undoubtedly to be found in that same internal heat which gives rise to the more sudden and violent disturbances, and thus we have a direct connection shown between volcanoes and coral reefs; the force which produces the former renders the existence the latter possible.

At one time it was customary to think that the present condition of the globe had been brought about by a series of catastrophes, but it now seems highly probable that the work has been mainly effected by the more gradual movements, and the lesson we learn is that it is not always the most obvious and startling of nature's works that are the most important, but that the most effective are those which work in silence, unheeded or unseen. Not only when with terrific violence the imprisoned gases burst their rocky prison-house and the earth seems to stagger beneath the blow; not merely when some fierce tornado or desolating hurricane sweeps with resistless energy across some fair region of the earth, spreading terror and desolation in its path, but in the calmest and softest summer's day, in the tiniest of ocean's wavelets that ripple on the shore, do

> **The giant ages heave the hill**
> **And break the shore, and evermore**
> **Make and break and work their will.**

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